FINAL REPORT

MaRSPlus Sensor System Electrical Cable Management and Distributed Motor Control Computer Interface

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Introduction

The success of JPL's Next Generation Imaging Spectrometer (NGIS) in Earth remote sensing has inspired a follow-on instrument project, the MaRSPlus Sensor System (MSS). One of JPL's responsibilities in the MSS project involves updating the documentation from the previous JPL airborne imagers to provide all the information necessary for an outside customer to operate the instrument independently. As part of this documentation update, I created detailed electrical cabling diagrams to provide JPL technicians with clear and concise build instructions and a database to track the status of cables from order to build to delivery.

Simultaneously, a distributed motor control system is being developed for potential use on the proposed 2018 Mars rover mission. This system would significantly reduce the mass necessary for rover motor control, making more mass space available to other important spacecraft systems. The current stage of the project consists of a desktop computer talking to a single "cold box" unit containing the electronics to drive a motor. In order to test the electronics, I developed a graphical user interface (GUI) using MATLAB to allow a user to send simple commands to the cold box and display the responses received in a user-friendly format.

MaRSPlus Sensor System

Background

The MSS instrument project is one of many descendants of a previous JPL project called the Airborne Visible/Infrared Remote Imaging Spectrometer (AVIRIS), which produces information in the form of data cubes like that shown in Figure 1. Still in operation today, AVIRIS has been extremely successful in providing NASA with useful information about Earth's surface and atmosphere since its first flight over ten years ago. Earth remote sensing data can be used for a number of reasons, some of which include the study of anthropogenic effects on Earth, such as urban sprawl and pollution, as well as natural effects like vegetation migration and ocean water movements. Airborne remote sensing is particularly helpful in situations where events happen unexpectedly and must be observed immediately, such as oil spills and forest fires.

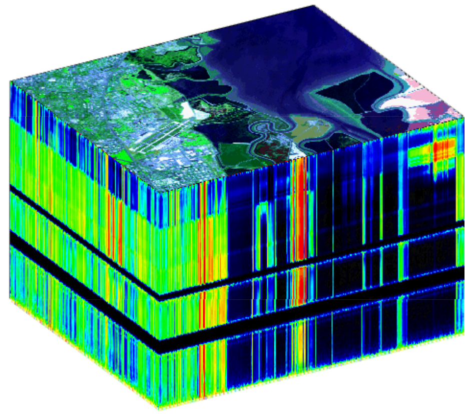


Figure 1: Imaging spectrometer data cube (1).

AVIRIS was conceptualized and built at JPL, and in flight it's operated by JPL employees, many of whom were intimately involved in the creation of the instrument. Their knowledge of the instrument is quite helpful when an issue occurs with the instrument during operation, since they can quite easily attempt to fix the issue either during or between flights. MSS is a set of three identical remote sensing spectrometers that are quite similar to AVIRIS in design. However, the project is different from AVIRIS in that the imagers are to be delivered by JPL to an outside customer who plans to operate them independently. It's very important for JPL to provide them with cohesive documentation on the instrument so they may familiarize themselves with it and be able to solve any operational issues as they arise. Therefore, as JPL was in the process of building the MSS instruments this summer, efforts were also made to update the existing instrument documentation.

Objectives

As part of the MSS documentation update, I was given the task of managing all the electrical cables for the instrument. This task was split into two main responsibilities. The first was to transfer the existing cable build information from a text-based spreadsheet to a more user-friendly format using diagrams with color-coded wires to show the pin-to-pin contacts between connectors. For a custom-designed instrument like MSS, JPL technicians must build most of the cables rather than using commercial off-the-shelf (COTS) cables. It's important to make the cabling instructions as simple and clear as possible for the technician building them to avoid mistakes in pin connections, wire gauge, length, wire twisting, etc. My goal was to create a single-page diagram for each cable that presented all necessary build information in an organized and readable format.

My second task was to create and maintain a database to track the build and test status of all cables. The database must keep track of information including the team member responsible for ordering a cable, the technician who is building a cable, the current build status of a cable (i.e. whether it's been ordered yet, when the technician expects to deliver it, etc.), and the testing status of a cable. With a fairly tight schedule, it's important to have and maintain a cable database to ensure the cables are ready in time for each imager to be assembled and tested.

Approach

To create the MSS cable diagrams, I chose to use Microsoft® Visio because of its fine-detail drawing capabilities and its ease of use. I was given a simple example diagram created by my mentor for a different project, from which I pulled many ideas about how to draw physical representations of cable connectors and the twists between two or more wires in a cable. I first drew a diagram for each cable in Visio showing the point-to-point contacts between the connectors on either end of the cable, and I included any special notes about how to build the cable in text boxes. Those diagram were then reviewed by my mentor and the MSS team member officially in charge of cables, and they both made suggestions about how to improve the diagrams, including a wire numbering system and a connection matrix showing the pin-to-pin contacts textually to help clarify any confusion the technician may have about the diagram. After implementing the suggested changes, we started sending diagrams to a technician for build, who was able to make more suggestions about how to improve the diagrams. While it took me about three weeks to create the initial diagrams, all of the suggestions throughout the following weeks led to many updates throughout the summer, and in fact I am still making more improvements to the diagrams in the last two weeks of my internship.

I used Microsoft Excel to create the cable status database because of its cell structure, which is helpful in organizing information. I first created a spreadsheet to track the status of each cable diagram, including information about if a cable was COTS, if the diagram was completed and ready for delivery to a technician, if the cable design was being modified, etc. Then I created a separate spreadsheet to track the build status of each cable. This spreadsheet reflected the status of a cable diagram with a color-coding scheme, as well as it tracked information about where the cable was in the build process. After review by the electrical project manager, columns were added to track delivery of cables from technician to the project, assign a priority level to each cable to help us determine the order in which to build cables, and track the testing status of cables. I then maintained the database throughout the summer as cables were built and tested. I communicated with the electrical cable head on a daily basis to make sure the database accurately reflected the status of all cables.

Results

Diagrams were created for all MSS electrical cables including all of the same information provided in the original build instructions, but in a more visually readable format, especially for those who are visual learners. By the end of the summer approximately half of a complete set of cables had been built by technicians using the new diagrams. The cable status database was created within the first few weeks of my internship, and throughout the rest of the summer it helped team members to decide which cables to build next, and to avoid accidentally ordering multiples of a single cable.

Discussion

I was able to complete my tasks for MSS within my time at JPL, and both the cable diagrams and the status database have proved to be quite useful as hoped. Creation of the diagrams also aided in finding some minor errors in some of the original build instructions, which was an unexpected benefit of the task.

Distributed Motor Control

Background

A typical JPL rover exploring the surface of Mars has what's called Central Motor Control (CMC), meaning the electronics associated with driving all the motors are located in one place, typically near the center of the rover. This is done so that those electronics can be packaged together to protect them from the harsh environments experienced on Mars, including large temperature fluctuations and radiation. The big problem with CMC is the extra mass it adds to the rover in the form of hundreds of pounds of electrical cabling connecting the central electronics to each motor, many of which are located in the rover extremities. The obvious solution to this problem is to implement Distributed Motor Control (DMC), where the electronics for driving a single motor are located next to that motor – effectively eliminating all the extra cabling. If the issues of temperature fluctuation and radiation can be resolved, DMC would be able to replace CMC on future rovers, freeing up mass space for other spacecraft systems.

Radiation is no longer a significant problem for DMC due to the commercial development of radiation-hardened or "rad-hard" electronics. Temperature fluctuations, however, are still problematic for DMC electronics. Specifically, the surface of Mars can reach temperatures as low as -130°C; at these low temperatures, some electronic components tend to fail due to decreased electrical conductivity. The goal of the DMC instrument project is, therefore, to create a motor-drive electronics package capable of operating in the full temperature range experienced on Mars (-130°C to 80°C) and demonstrate that DMC is an valid alternative to CMC in future JPL rovers like the proposed 2018 mission.

Objectives

The current version of DMC consists of a single electronics board that houses a field programmable gate array (FPGA), which controls all the surrounding electronic components in order to drive a motor. In order for the system to operate, the FPGA must be programmed and commanded via a serial connection to a regular desktop or laptop computer. In order for the team to test the electronics, I was tasked with developing a computer interface to allow a user to send simple commands to the board and display the responses received in a user-friendly format.

Approach

It was recommended to me that I use MATLAB to create the computer/board interface because of the software's user-friendly GUI Design Environment (GUIDE) and the extensive help documentation provided by MATLAB. I based the visual design of the GUI on another GUI previously designed for an earlier DMC design, and I used some of that GUI's code as a jumping-off point. I first created the GUI format to allow a user to input certain values of the command sequence, which was made up of 52 bytes of data. Much time was spent figuring out how to convert the input values to the right form (decimal, binary, or hexadecimal) and combine them in the right order to form the command sequence. Once that was sorted out, code was added to split up the values of the FPGA response and display those values in the GUI in close to real time. After send/receive capabilities were achieved, I added in a timer to send commands and receive responses every 0.1 seconds, and I included code to log all commands sent and responses received in a text file for later analysis.

Results

The current version of the DMC GUI is shown in Figure 2. The top half of the view is reserved for command input values, as well as a “SET” button to update command line with the values currently in the text input boxes and a “DEFAULT” button to return all text boxes to their original values. The bottom half of the view displays all the response data from the FPGA, updating the values every 0.5 seconds. The timer button in the upper right-hand corner starts and stops the timer that sends commands and receives responses. Each time the GUI is opened, a new text file is created to log all commands and responses, one of which is shown in Figure 3.

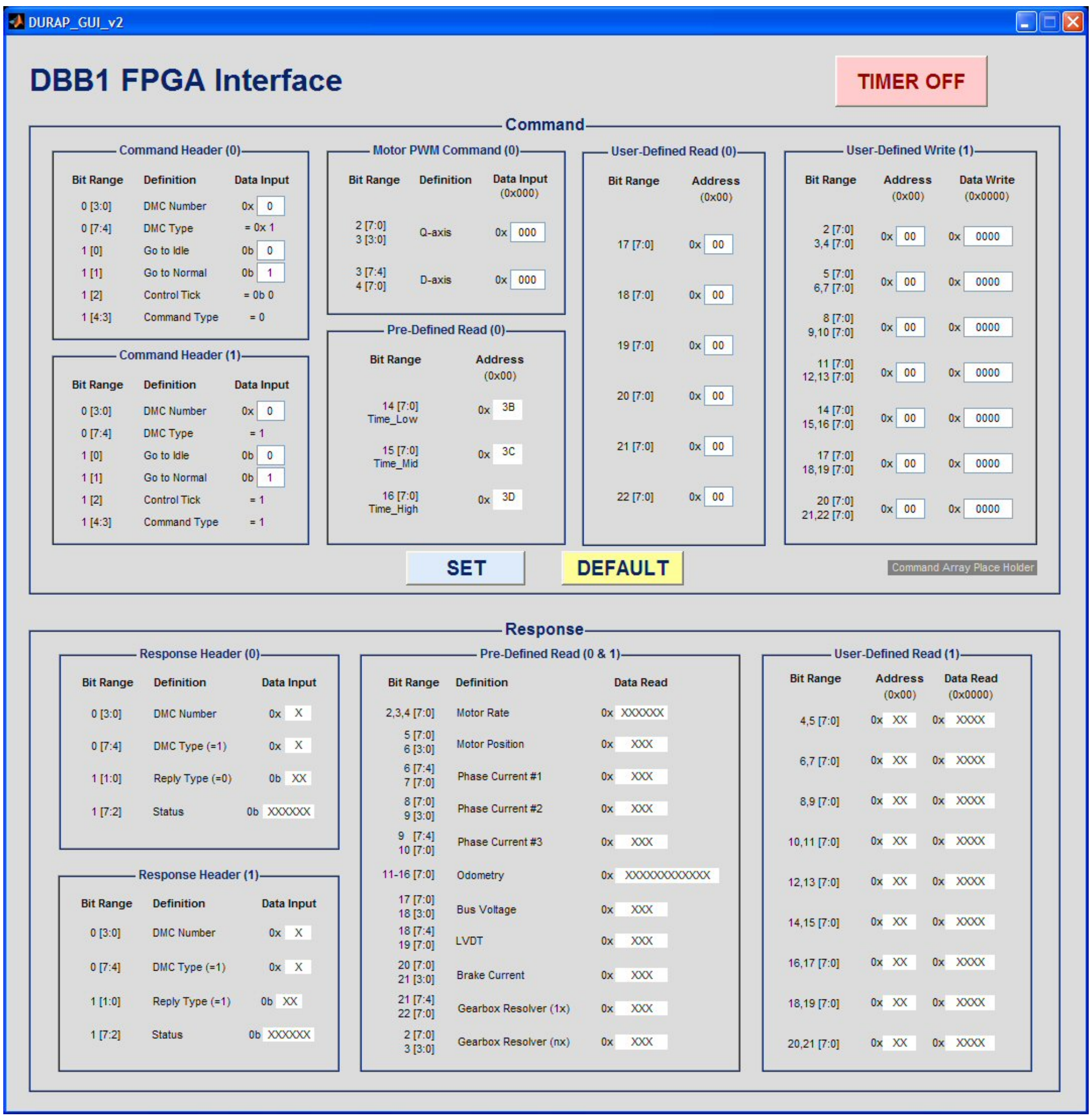
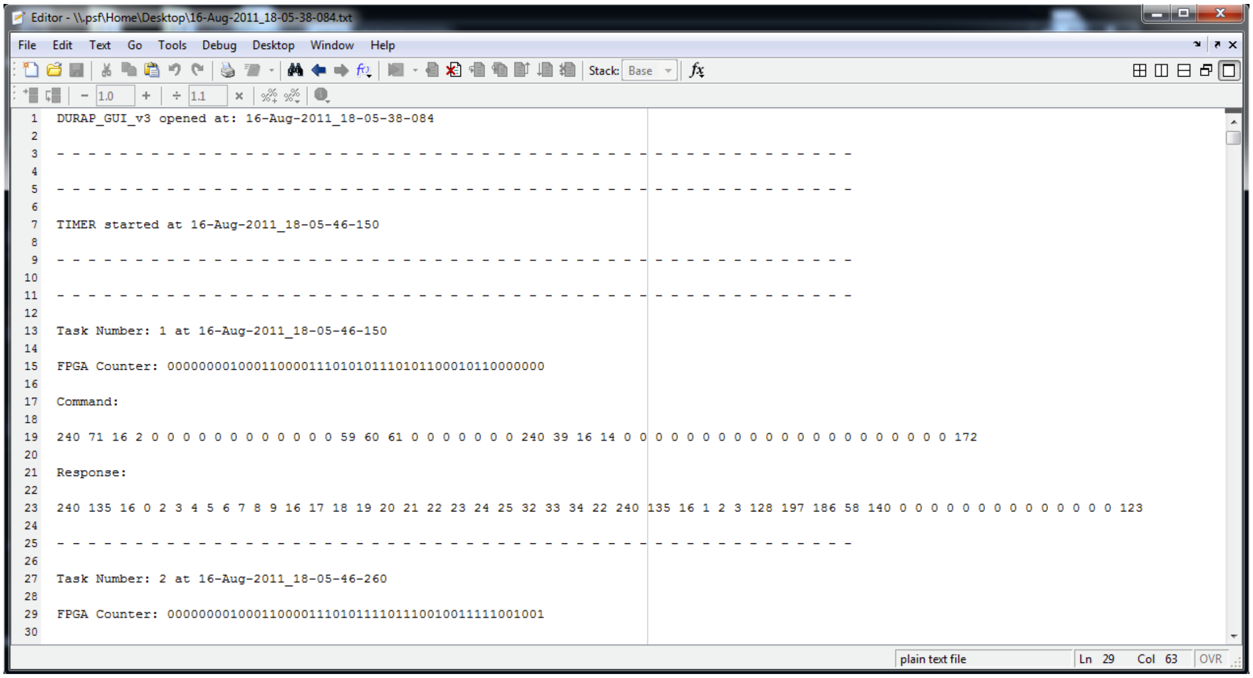


Figure 2: DMC GUI view.



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DURAP_GUI_v3 opened at: 16-Aug-2011_18-05-38-084

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TIMER started at 16-Aug-2011_18-05-46-150

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Task Number: 1 at 16-Aug-2011_18-05-46-150

FPGA Counter: 000000001000110000111010101110101100010110000000

Command:

240 71 16 2 0 0 0 0 0 0 0 0 0 0 0 0 59 60 61 0 0 0 0 0 0 0 240 39 16 14 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 172

Response:

240 135 16 0 2 3 4 5 6 7 8 9 16 17 18 19 20 21 22 23 24 25 32 33 34 22 240 135 16 1 2 3 128 197 186 58 140 0 0 0 0 0 0 0 0 0 0 0 0 0 0 123

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Task Number: 2 at 16-Aug-2011_18-05-46-260

FPGA Counter: 000000001000110000111010111101110010011111001001
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Figure 3: DMC GUI log file view.

Discussion

The GUI has worked quite successfully in testing so far, and it has exceeded the original expectations for the task. Use of the GUI with the working board has helped us to realize some changes could be made to the GUI structure to make it even more user friendly, including added spaces in the response section to display real-world values, such as number of RPM, next to their hexadecimal counterparts. I will be using some of my little time left at JPL to complete these improvements, and I expect once the board is fully tested on its own and is ready to be tested with a motor, more improvements will be made by other project members.

Conclusion

My experiences working on MSS taught me much about effective communication among project members. I had to communicate with all of the team members often to make sure my diagrams and cable status database accurately reflected any cable design changes. The lines of communication should stay active after I leave, and the diagrams and status database should be maintained by another project member to ensure the cable build and test processes continue smoothly.

I came into the DMC project as a MATLAB novice at best, and I am honestly impressed to see how much I was capable of learning as I created the GUI. I expect and hope that the GUI will serve the project well in testing until it moves to the next stage and more advanced interface software will be created. A suggested improvement to the GUI in the near future would be to include real-time graphing capabilities inside the GUI window so that values can be visually monitored as they change over time.

Acknowledgements

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